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Grounding contingency plan for intact double hull tanker



A.W. Hussein^{a,*}, U.M. El-Dessouky^b, H.S. El-Kilani^a, E.H. Hegazy^a

^a Dept. of Naval Architecture & Marine Engineering Port Said University, Port-Said, Egypt

^b General Authority of Port-Said Ports, Egypt

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Abstract Ship grounding is a hazard which requires enormous caution when occurs. No matter how secure a grounded ship may appear, she is in a dangerous position. In most cases, rapid refloating is desirable to remove the ship from a place of danger, to reduce stress on the hull and to decrease the risk of pollution. The usual action taken is reducing the weight of the ship, which requires the help of salvage team and consequently causes high cost. Another alternative is weight transfer from tank to tank until ship refloats; this has to be done with extensive not to cause double loss.

This paper proposes practical support that would help the captain make the right decisions at the moment of the casualty. The plan is summarized in a chart which gives direction to the captain how to refloat the ship by transferring weight from cargo tanks to ballast tanks. Since the ship strength is of major concern, strength check is included in the plan. The proposed Grounding Contingency Plan “GCP” for intact double hull tanker is suggested to be prepared in design to facilitate the decision making for the captain and indicates the direction of action to minimize the risk.

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1. Introduction

An unexpected incident, such as grounding, can lead to complex technical challenges which require fast and effective response. A stranded ship is in a position not intended by her designers, builders, or operators and is subject to very different forces and conditions than when in normal service. The grounding condition and the environment are the principal sources of forces on a stranded ship. Grounding salvage is time-critical; environmental conditions may improve or wor-

sen with time. A casualty's condition will deteriorate fast unless appropriate action is taken. The longer a casualty is left without professional assistance, the greater the risk to staff, environment, the vessel and its cargo.

Grounding is among one of the most frequent maritime accidents, sometimes with catastrophic consequences for human life and maritime environment such as the Exxon Valdez and Costa Concordia accidents. Consequently, the rapid salvage of the ship is always mandatory and the delay of this decision may subject the ship and the environment to catastrophic consequences. The longer the ship remains in a stranded position, the higher the possibilities for a ship to suffer severe damages and a pollution event to occur.

* Corresponding author.

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If the ship is intact after grounding, there are two options for re-floatation: lightening weight or transfer weight within the ship tanks to free the ship. Weight Lightening is usually the common method to refloat the ship. The salvage team would have to discharge oil from the tanks around the grounding area until the ship is free. While weight transfer within the ship tanks is usually recommended if there are some empty tanks in the ship. This reduces the cost of freeing the ship but requires assuring that the new weight distribution will not affect the ship's stability or strength.

2. Emergency response services and problem definition

Safety at sea has improved considerably in recent decades. Greater transparency on the condition of vessels, more reliable machinery, sophisticated shipboard navigational systems and the mandatory ISM Code have contributed to higher safety standards. Despite such progress, serious accidents still occur. According to current regulations oil tankers must have prompt access to computerized, shore-based damage stability and residual structural strength calculation programs. **MARPOL** Regulation 1/37(4), as circulated by Resolution MEPC.117 (52), states that oil tankers of 5000 dwt or more require access to shore-based damage stability and residual structural strength calculations. **MARPOL** 73/78 Annex I, Regulation 26 requires a Shipboard Oil Pollution Emergency Plan (SOPEP) for all tankers of 150 gross tons or more and all other vessels of 400 gross tons or more. While it does not require, it strongly suggests that, when there is excessive damage, consultation with shore-based technical assistance is appropriate before taking any action that may jeopardize the vessel [1].

US Coast Guard requirements of **Oil Pollution Act** OPA 90 in 33 CFR 155.240 for oil tankers and offshore oil barges stated that owners are required to have "prearranged, prompt access to computerized, shore-based damage stability and residual structural strength calculation programs."

The **International Safety Management** Code (ISM Code), Section 8, requires the company to establish procedures to respond to potential emergency shipboard situations, including the use of drills and exercises to prepare for those emergencies. The **ABS RRDA** program can be a valuable resource augmenting a company's emergency preparedness program.

Now the question is: "Who is prepared to assess the stability and residual strength of a damaged ship with the required accuracy and speed?". Some Classification societies had already offered a solution. American Bureau of Shipping **ABS** provided **Rapid Response Damage Assessment** (RRDA) program which gives the ship owner and operator with the essential technical support needed in the critical hours after a vessel is involved in a casualty [2]. A team of naval architects, marine engineers, master mariners and support staff provides the ship owner access to the professional resources needed to conduct the essential structural and stability calculations in the event of an incident that could result in the loss of the vessel, loss of all or part of its cargo or lead to pollution of the marine environment.

The **Det Norske Veritas – Germanischer Lloyd** provided the **Emergency Response Service** (ERS™). It helps in making the right decisions in case of collision, fire, grounding or other damage scenarios. It gives the technical advice: Buoyancy,

damage stability, residual strength, grounding aspects, potential oil outflow, lightening sequence [3].

The Nippon Kaiji Kyokai **ClassNK** provided **PrimeShip-Emergency Technical Assistance Service** (ETAS). PrimeShip-ETAS is an emergency service designed to help ship owners and operators ensure ship safety and prevent or minimize the effect of marine pollution in the event of a serious ship casualty such as stranding, collision or explosion. Working closely with the owner and salvage team, the ClassNK ETAS team is often the brains behind the brawn, making sure that salvage operations do not make the situation worse, while minimizing environmental impact. The ClassNK ETAS team can swiftly calculate stability at damage condition and residual longitudinal strength [4].

Early in 1985, Clay [5], used a software called "Ship Hull Characteristics Program" (SHCP) to evaluate the likelihood of exceeding longitudinal strength of stranded tankers in wave. The author modeled ground reaction for hull strength calculations. The authors addressed the need to apply microcomputer technology to salvage as this would increase hull survivability and decrease the chance of pollution. It was proposed that new technologies can augment a salvor's feel for the dynamics involved in salvage engineering.

The **Oil Pollution Act** of 1990 (OPA 90) established standards for the prevention and removal of, and liability for, oil pollution to the marine environment. It set strict requirements for any tanker trading in the U.S. waters, including the requirement of maintaining a Vessel Response Plan (VRP). The VRP specifies pollution prevention and removal procedures and identifies Qualified Individuals, salvors, and resources to assess damaged stability and residual strength. Treglia et al. [6] reported a tanker casualty and highlighted the cooperative response effort of the responders, the role of the Qualified Individual, and the importance of accessibility to a pre-arranged stability and strength assessment program.

Piccolo and Vasconcellos [7], highlighted the main technical aspects related to salvage operations as inspection of the casualty, including cargo and flooding, inspection of the site, including weather conditions, availability of material and equipment, stability and strength calculations, grounding reaction calculation, cargo transshipment or jettisoning, patching and dewatering, pulling with usage of beach gear or tugboats and dewatering and assisted refloating. Examples and case studies were included and new research areas were indicated.

Varsami et al. [8] performed several simulations using TransasNavi Trainer 5000 Simulator. They tried to analyze the possibility of refloating a ship by using her own means of propulsion, namely her main engine, in combination with ballasting and de-ballasting the stern tanks and the ones on the portside and starboard side.

El-Dessouky et al. [9] discussed the possible hazards related to hull girder bending during refloating of stranded intact double hull tankers. The authors used the commercial software HECSALV to analyze a number of hypothetical scenarios in order to identify the hazards related to hull girder bending due to the refloating of a stranded intact double hull tanker. The scenarios are generated according to different loading conditions, pinnacle positions, tide and wave heights.

El-Dessouky et al. [10] studied the refloating scenarios of an intact-grounded tanker. Many scenarios were assumed, using the commercial software HECSALV™, varying the

longitudinal, transverse, and vertical positions of the pinnacle. The authors introduced a set of curves which would help the shipmaster to define the amount of weight to be removed from the ship, and to check the strength during refloating.

This research suggests a solution for the grounding intact double hull tankers. The solution is easy to use and it does not need contact with any party. It is called *Grounding Contingency Plan “GCP”*. It consists of two set of curves, which have to be prepared in the design stage. It allows the ship master to free a grounded intact ship without the help of salvage team to make weight transfer; it depends on weigh management. Yet, it assures that the ship will not be subjected to stability or strength hazards. Not all the grounding scenarios are safe; the *GCP* shows the ship master if he can handle the situation or he has to call a salvage team. Defining the position of the pinnacle and the height of tide gives the ship master the opportunity to judge if he can re-float the ship using weight management. If the ship is in safe situation a re-floating can be done using weight management, and the *GCP* gives the ship master the guidance to move the weight from cargo tanks to ballast tanks assuring safe refloating.

3. Data generation

To generate the data required for the analysis the commercial software HECSALV™ is used. HECSALV™ is salvage and emergency response software used by naval architects, salvage engineers, ship owners, classification societies, and military organizations. During a vessel emergency your most valuable assets are time and confidence. Starting with the last known departure condition, HECSALV™ allows the user to quickly collect and process available data, define the extreme bounds of the problem, and evaluate multiple scenarios for remedial action. The user can quickly and automatically update the entire analysis from beginning assumptions to latter stage pump allocations, producing a refined and carefully considered salvage plan to follow. HECSALV™ is used by naval architects and ship design team to:

- Design and evaluate various hull forms.
- Create detailed 3D vessel model with all the spaces.
- Conduct initial sizing and parametric studies.
- Layout general arrangement and optimize cargo spaces.
- Develop load cases review resulting intact and damaged stability.
- Design optimum structural cross sections.
- Develop allowable bending moments and shear force envelopes.
- Produce trim and stability booklets.
- Create ballast water management plans.
- Create ullage and sounding tables.
- Develop required GM curves according to various regulatory criteria.

HECSALV™ assists salvage engineers in the salvage of free-floating and stranded ships by providing initial engineering estimates for planning and mobilizing a salvage mission and by providing in-depth engineering assessments during a salvage operation. It is applicable to ships of any type; floating docks, semi-submersibles, tension legs platforms TLPs, spars and heavy lift ships.

3.1. Virtual scenarios

Virtual scenarios are generated using HECSALV™. The ground pinnacle is assumed to be located in ten longitudinal positions, and for each longitudinal position five transverse positions are studied as follows:

- At the centerline; $\alpha = 0$.
- 10% away from the centerline; $\alpha = 0.1$.
- 20% away from the centerline; $\alpha = 0.2$.
- 30% away from the centerline; $\alpha = 0.3$.
- 40% away from the centerline; $\alpha = 0.4$.

For each of these 50 scenarios, 6 tide levels above the pinnacle are attributed as shown in Table 1. This makes a total of 300 grounding scenarios. For all scenarios, it is assumed that the ship stranded one mud pinnacle remains intact, with no deflection, no residual stress, and no corrosive damage and with 95% full loading condition. The ship is modeled and the weight of each tank is indicated. The parameters of each grounding scenario are input, and for each case, the output required is:

- Metacentric Height, GM_T : after grounding.
- Maximum Bending Moment, β : given as a percentage of the maximum allowable bending moment which is the maximum bending moment based on yield strength of the ship.

4. Case study

In this study, the virtual grounding scenarios generated are used to study the possible solutions for refloating a stranded double-hull tanker, referred here as Tanker A, having the following particulars, Table 2.

The typical configuration of the double-hull tanker is shown in Fig. 1. This ship is a sample vessel modeled by HECSALV™, and data of this ship including hull and compartment geometry, lightship weight distribution and structural section properties are provided. The study assumes the tanker with

Table 1 Tide level above pinnacle.

No	Symbol	Water height/ship design draft
1	A	0.90
2	B	0.78
3	C	0.66
4	D	0.54
5	E	0.42
6	F	0.30

Table 2 Ship properties.

L.O.A.	280 m
L.B.P.	246 m
Breadth	48 m
Depth	24 m
Deadweight	150,000 t

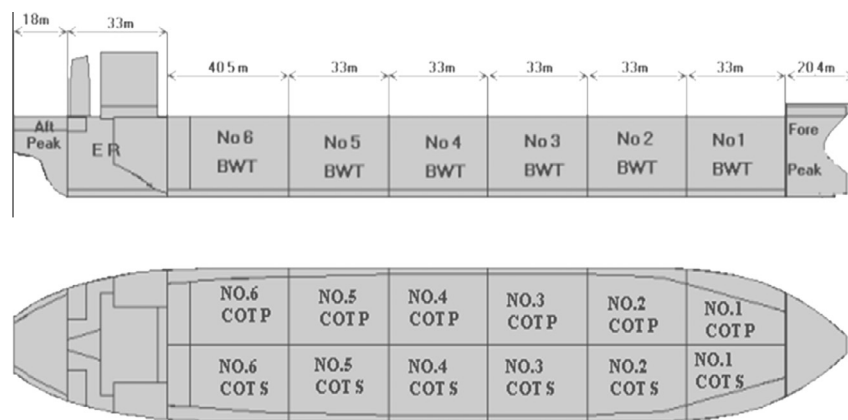


Figure 1 Tank arrangement for Tanker A [6].

Table 3 Intact trim and stability summary.

Item	Weight (t)	Stability calculation	
Light ship	22,849		
Cargo oil	149,247	Static heel angle	0°
Fuel oil	2256	VCG (m)	13.048
Diesel oil	170	LCG (m-AP)	139.89 F
Lube oil	66	TCG (m-CL)	0.003 P
Freshwater	498	KM _T (m)	19.704
Displacement	175,393	GM _T (m)	5.095
Drafts		Strength calculation	
AP	16.591 m	Shear force (MT)	6136 at 218 F m – AP
FP	16.421 m	Bending moment (m MT)	420,099 S at 135.5 F m – AP
Amidships	16.506 m	Shear allowable %	34 at 218 F m – AP
Trim	0.17 m (A)	Bending moment allowable %	44 at 135.5 F m – AP

95% full loading condition is having an even keel at draft 16.5 m before stranding. Table 3 shows intact trim and stability information for the ship.

5. Data analysis

The critical grounding scenarios in which refloating the ship might lead to catastrophic consequences are depicted among the 300 grounding scenarios simulated. The results of the analysis are analyzed to study the situation of the ship after grounding from stability and strength points of view. The following subsections present the results when the pinnacle is located at three transverse locations namely $\alpha = 0$, $\alpha = 0.1$ and $\alpha = 0.3$.

5.1. Stability hazard

Fig. 2 shows the relation between the longitudinal position of the pinnacle and GM_T after grounding when the pinnacle lies at the centerline of the ship ($\alpha = 0$). The calculations are made for different water levels (from A to F). From the figure, one can conclude that when the pinnacle lies between 30% and 70% of the length, the GM_T will be negative especially when the water level above the pinnacle is low (C, D, E and F). This leads to stability hazard.

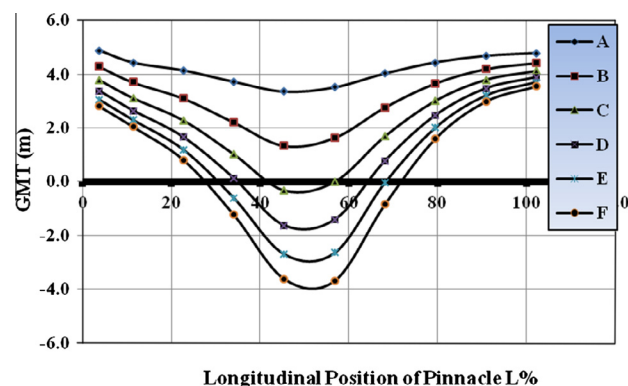


Figure 2 GM_T versus longitudinal position of the pinnacle for different tides ($\alpha = 0$).

Figs. 3 and 4 show that when the pinnacle is located away from the centerline, no stability hazard is apparent since all GM_T values are positive; nevertheless, stability criteria may be unfulfilled for some scenarios. Stability hazards would therefore need more detailed investigations, but as a general conclusion it may be seen that if the pinnacle is away from the centerline of the ship, refloating the ship is possible for any water level.

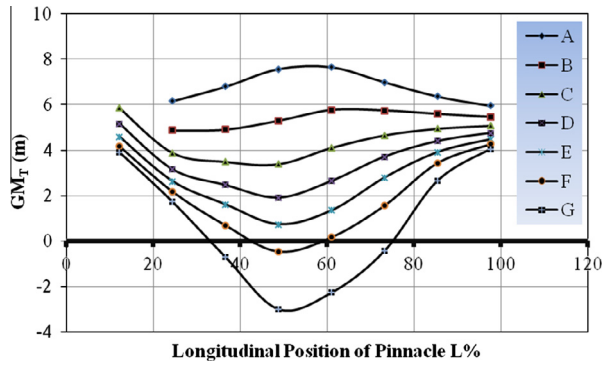


Figure 3 GM_T versus longitudinal position of the pinnacle for different water levels ($\alpha = 0.1$).

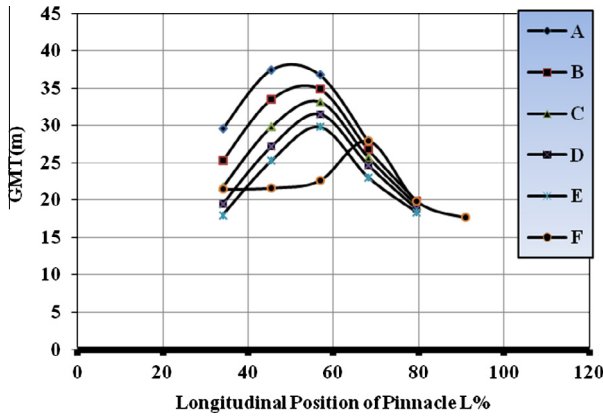


Figure 4 GM_T versus longitudinal position of the pinnacle for different tides ($\alpha = 0.3$).

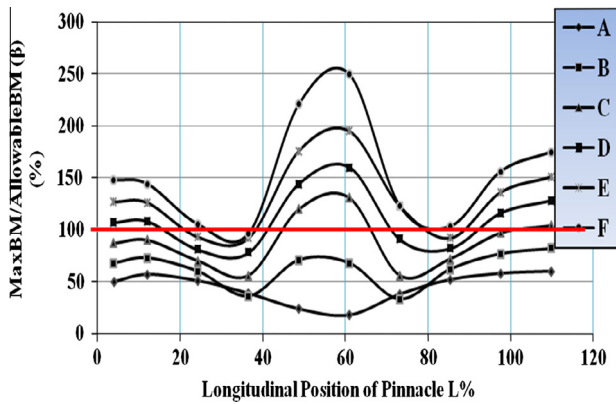


Figure 5 β versus longitudinal position of the pinnacle for different tides ($\alpha = 0$).

5.2. Strength hazards

The relation between the maximum bending moment after grounding and the position of the pinnacle (longitudinally and transverse) is also studied. Fig. 5 shows the relation between the longitudinal position of the pinnacle and the maximum bending moment. The maximum bending moment is

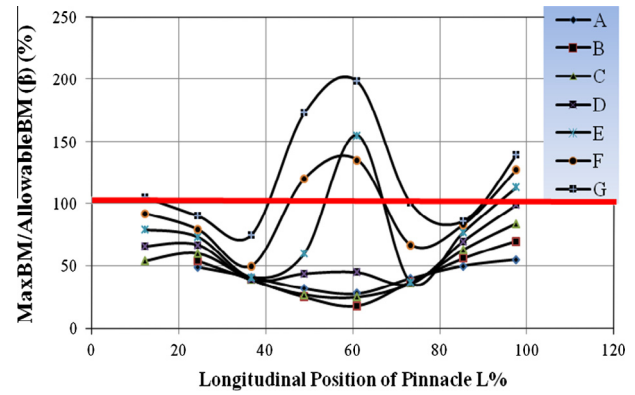


Figure 6 β versus longitudinal position of the pinnacle for different tides ($\alpha = 0.1$).

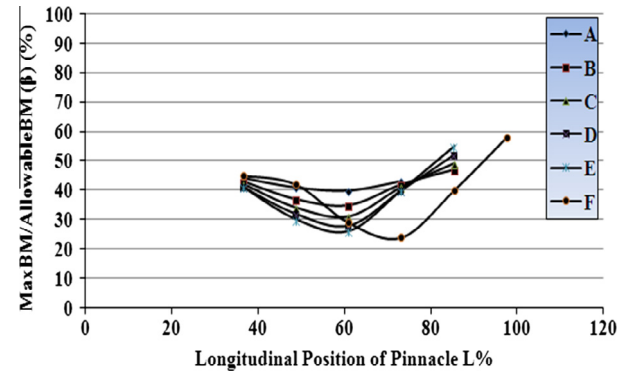


Figure 7 β versus longitudinal position of the pinnacle for different tides ($\alpha = 0.3$).

presented as a ratio of the Maximum allowable bending moment (which is the maximum bending moment based on yield strength of the ship); this ratio is referred as β . If the ratio β exceeded 100%, this is strength hazard.

Fig. 5 shows that there is always an expected strength hazard unless the height of the water above the pinnacle is high; cases A and B. Fig. 6 shows that when the pinnacle is located at 10% B the strength hazard exists when the tide is low especially if the pinnacle is located at the mid-region, while Fig. 7 shows that if the pinnacle lies away from the centerline of the ship, there will be no expected hazards.

5.3. Critical areas

According to the above analyses, the following conclusions are extracted:

- There is always strength and stability hazards if the pinnacle lies at the centerline of the ship.
- The mid-region of the ship length (35–75% L) is a critical area for grounding, especially at low tide.
- The height of the water above the pinnacle is a very important factor when studying grounding. The higher the tide, the safer the situation of the ship from both stability and strength points of view.

6. Refloating scenario

The conditions of grounding are rarely defined at the beginning and often are not completely defined during the salvage operation. In this study, refloating the ship is achieved by weight management. The cargo from the tanks close to the grounding area will be moved to the farthest ballast tanks. More than one tank might be used until the ship float free. Moving weight from a location to another causes moment. This moment will be referred as **Refloating Moment**, which is the moment required for freeing the ship. The details of the required piping system and valves are well explained in El-Desouky, 2014 [11].

The idea of the work is to move cargo from the cargo tank near to the grounding area to the farthest ballast tanks and to define the **Refloating Moment** and the corresponding trim angle after moving the cargo using HECSALVTM. At each step, the metacentric height GM_T and the maximum bending moment (β) are defined to check stability and longitudinal strength. In some cases, it has been found that it is not possible to free the ship since the required **Refloating Moment** is very large. In such cases, the only available solution is lightering the ship.

Fig. 8 shows the results of the calculations when the pinnacle is located at B/10 from the centerline ($\alpha = 0.1$). These calculations are carried out for scenarios where the pinnacle is at the fore region (80–100% L). The mid region is not studied since it represents critical stability and strength hazards zone where weight management within the vessel may not be the proper solution to save the grounded ship; lightering would be a must.

If the pinnacle is located at $\alpha = 0.1$ and the water level above the pinnacle is 80% of the draft, this means that to refloat the ship a reverse moment with the value of 11.25 Mton m should be applied. From the figure it is obvious that the maximum bending moment is 68% of the allowable bending moment, which means no strength hazard exists. The required Refloating Bending Moment, 11.25 Mton m, is achieved by moving certain amount of fluid from a location to another to refloat the ship. If the distance between the center of the cargo tank close to the grounding area and the center of ballast tank used to lighter the tank is L , then the required weight to free the ship is $(11.25 \text{ Mton m})/L$, Fig. 9.

Repeating the calculations for the 300 scenarios defined in 0, one can achieve four curves for the relation between the **Refloating Moment** and the water level and another four curves

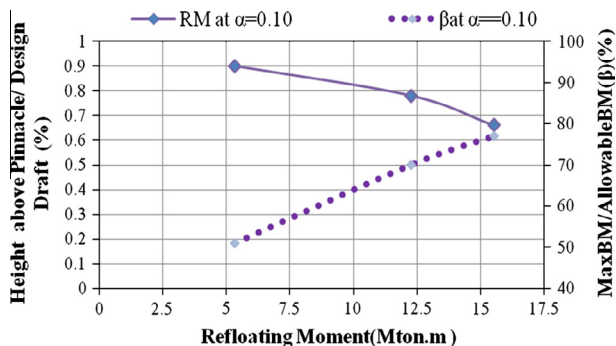


Figure 8 Required refloating moment for different water levels above pinnacle.

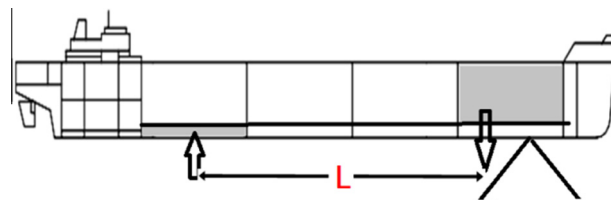


Figure 9 Weight transfer from Cargo tank to Ballast Tank.

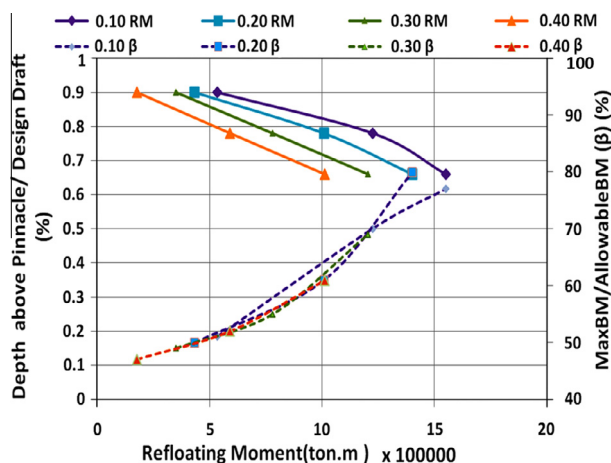


Figure 10 Refloating moment guide (RMG) curve.

for the relation between the **Refloating Moment** and the maximum Bending moment, Fig. 10. If the height of water above the pinnacle is less than 65% the draft the required refloating moment cannot be achieved by weight transfer through the ship; the only option available is to lighter the ship weight using external barges with the help of salvage team. If the height of the water above the pinnacle is more than that 65% the draft, one can interpolate for the transverse location of the pinnacle to find the required refloating moment, and check simultaneously the strength.

Fig. 10 is called **Refloating Moment Guide RMG**. The input data required to use these set of curves are the transverse location of the pinnacle and the height of water above it. Using these input data; one can define the required moment to refloat the ship, which is explained to be “the amount of cargo and destination tank” as will be shown in the next section.

7. Cargo transfer sequence

To achieve the required moment cargo is transferred to Ballast Tank no. 6 until it is full. Then more cargo is transferred to Ballast Tank no. 5, then no. 4 and so on until the ship floats free. Fig. 1 shows the tanks arrangements.

Knowing the transverse position of the pinnacle and the height of water above it, one can define the required moment to free the ship using Fig. 10. One can also check the maximum bending moment applied on the ship to assure safety during floatation. Following the same sequence of cargo transfer for all grounding scenarios allows us to draw Fig. 11, which gives the sequence of cargo transfer recommended for the defined transverse location of the pinnacle.

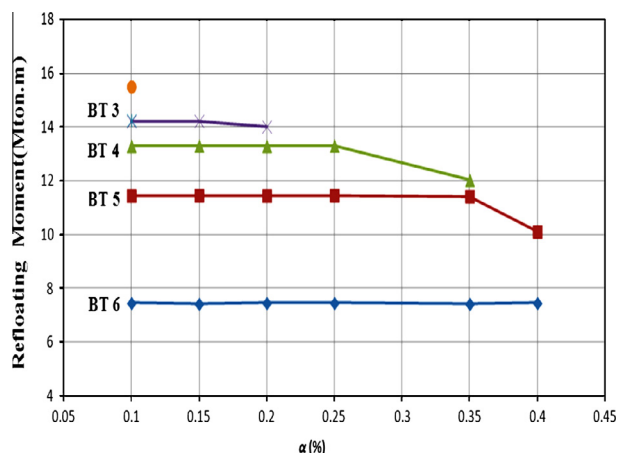


Figure 11 Recommended transfer sequence.

If the pinnacle is located at $\alpha = 0.1$ and the height above it is 80% of the draft, then the required moment is 11.25 Mton m, as calculated from Fig. 10. Using these data in Fig. 11, one can take the decision that cargo is transferred to Ballast Tanks no. 6 and no. 5. If the pinnacle is located at $\alpha = 0.2$ and the height above it is 70% of the draft, then the required moment is 12.5 Mton m. From Fig. 11 one can take the decision that cargo is transferred to Ballast Tanks no. 6, no. 5 and no. 4.

8. Conclusions

When a ship goes aground she has to be removed from the place of danger, to reduce stress in the hull and to decrease the risk of pollution. Refloating the grounded ship is usually done using salvage team, which costs money and takes time. In this paper, a quick and safe solution is proposed to facilitate making the decision. If the pinnacle is located at the centerline of the ship or at mid region – (35–75% L from AP) – the proposed method is not valid. It is valid if the pinnacle is located at the fore region or the aft region.

The proposed method suggests cargo transfer from cargo tank near the grounding area to the farthest ballast tanks, that causes reverse moment which will consequently free the ship from grounding. The *Refloating Moment Guide RMG* is proposed to tell the ship master whether to use the proposed method or to ask for the help of salvage team. At the same time, if the proposed method is valid for that scenario, the *RMG* tells the ship master the value of the moment required to free the ship. *Cargo Transfer Sequence* curve gives the captain the direction to move. It shows which ballast tanks can be

filled to achieve the required refloating moment. The two sets of curves are called *Grounding Contingency Plan “GCP”*. Using these two sets of curves, the ship master will be able to refloat the ship while he is sure that it will float safely.

Although these calculations are done for the scenarios when the pinnacle is located at the fore region (75–100% L), it is recommended that the two sets of curves are calculated for both fore (75–100% L), and aft region (0–35% L) to include all grounding scenarios. It is also recommended that these curves are prepared in the design stage. Accordingly, all the necessary outfitting and pipelines should be fitted to the ship during construction.

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